

## REMARKS & ARGUMENTS

The inventors have carefully studied the outstanding Office Action. The following response is intended to be fully responsive to all points of rejection raised by the examiner and is believed to place the application in condition for allowance. Claims 1-13 were withdrawn from further consideration pursuant to 37 CFR 1.142(b) as being drawn to a nonelected invention. Claims 14-33 are pending. In consideration of the arguments presented below, reconsideration of this application and allowance of all of the pending claims, as amended, are respectfully requested.

### Claim Amendments

Claim 14 and the appropriate dependent claims (15 and 17-31) have been amended by adding the limitations that the "liquid etchant" be an "aqueous etchant solution", and that the "solid" be an "inorganic solid". These limitations distinguish the present invention from the prior art involving removal of an organic photoresist film using commercial strippers comprising organic stripper species. Support for the "aqueous etchant solution" amendment is provided in the specification *inter alia* by paragraphs [0238] and [0239] of the published application. The nonaqueous etchant solution "EG +HF" has been deleted from claim 32. The solids discussed in the specification are "inorganic" silicon or silicon containing solids as indicated *inter alia* in paragraphs [0014], [0016], [0238] and [0255] of the specification.

Claims 14 and 15 have also been amended to indicate that there is at least one byproduct etchant species formed and present in the aqueous etchant solution as etching proceeds. This is discussed *inter alia* in paragraphs [0252] - [0255] of the published application. Inclusion of etchant byproducts in the model of the algorithm, and the algorithm itself, are discussed *inter alia* in paragraphs [0325], [0275] and [0286].

Claims 14 and 16 have also been amended by adding "...over the predetermined spectral range...", which is in agreement with the first and second lines of the step of performing in claim 14.

Claim 15 has been amended to reflect the claimed spectral range and is supported *inter alia* by original claim 33. Claim 33 has been cancelled without prejudice.

Claim 20 has been amended to rewrite the anions in more conventional nomenclature based on the acids from which they derive. Anions have been added which are derivable from

the acids mentioned in the etchant discussion in paragraph [0238] and original claim 32.

Claim 32 has been amended by replacing "BOE" (which stands for the well-known commercial "buffered oxide etch") by its components (HF:NH<sub>4</sub>F mixture).

Claims 34 and 35 have been added and are supported *inter alia* by material in paragraphs [0014], [0016], [0238] and [0255] of the specification.

Claim 36 has been added and is supported *inter alia* by material in paragraphs [0325], [0275] and [0286] of the specification.

Other claim amendments have been made to correct matters of form. For example, "comparing step" in claims 22-24 and 27-28 has been changed to "step of comparing". Minor changes have been made (for example, insertion of "a") to provide proper antecedent basis.

#### ***Claim Rejections - 35 USC §102***

Claims 14-16, 18, 21-24, 26, 28, 32 and 33 stand rejected under 35 USC §102(b) as being anticipated by U.S. Patent 6,203,659 to Shen et al.

The invention of Shen et al. is directed toward monitoring the quality of a photoresist stripper solution by detecting photoresist materials that accumulate in a stripper solution. Such stripper solutions are used to completely strip portions of photoresist films in patterned areas on semiconductor (silicon) wafers as part of processes used to form printed circuitry on semiconductor wafers. In the Shen et al. invention, absorption of infrared (IR) radiation by the stripper solution in the wavelength range 2000 – 15000 nm (column 2, lines 3-7) is used to detect photoresist materials, which are organic materials containing organic bonds that absorb infrared radiation (column 4, lines 17-23) in this wavelength range. According to Shen et al., the relative intensity of infrared radiation passing through the stripper solution is compared to a threshold value, and an alarm is sounded if this intensity falls below a predetermined threshold value (column 2, lines 46-49). In this case, the stripper solution is filtered to remove accumulated photoresist materials. Note that photoresist stripping is self-limiting (stops when all of the photoresist film within the exposed pattern area is removed) so that accurate measurement of the photoresist stripping rate is practically unimportant.

In contrast, the present invention as indicated in currently amended claim 14, requires: (1) use of an aqueous etchant solution containing inorganic etchant species; (2) use and etching of an

inorganic solid; (3) the production of byproducts of the inorganic etchant species acting on the inorganic solids, the byproducts themselves having etchant properties; and (4) an algorithm which *inter alia* takes these etchant byproducts into account.

For example, etching of silicon wafers in hydrofluoric acid etchants is provided by HF, F<sup>-</sup>, HF<sub>2</sub><sup>-</sup>, H<sup>+</sup> and OH<sup>-</sup> species that exist in equilibrium in the etchant solution. In this case, the etch rate may be increased by adding etchant (HF, for example), or decreased by diluting the etchant solution with water. Additionally, and not considered in the cited prior art, etching of silicon wafers by HF produces an even more powerful etchant fluorosilicic acid (H<sub>2</sub>SiF<sub>6</sub>) and substituted fluorosilicic acids (Si<sub>i</sub>F<sub>j</sub>(OH<sub>2</sub>)<sub>k</sub> where i+j+k=6), as discussed in paragraphs [0252] - [0255] of the published application. Without taking these fluorosilicic and substituted fluorosilicic acids into account in the algorithm **and model thereof**, processing control is not truly achievable.

Photoresists and photoresist strippers as used by Shen et al. are organic materials. A typical photoresist contemplated by Shen et al. (a ketene and an ester) is shown in Fig. 2 of the Shen patent, and typical stripper species (monoethanol amine and dimethyl sulfoxide) are described in Shen et al. (column 4, line 15). Therefore, both the strippers and photoresists used by Shen et al. are organic materials as they are in substantially all photoresist and stripping operations in the semiconductor industry. The present invention, on the other hand, is directed towards etching of inorganic solid substances with aqueous etchant solution containing inorganic etchant species, as is common in the semiconductor industry.

Additionally, Shen et al nowhere discusses or even suggests byproduct species having etchant properties being formed as a result of the etchant etching the solid, which is required in amended claim 14 and is incorporated into the inventors' process control algorithm.

Finally, it is clear that since Shen et al. contemplate and discuss use of organic photoresists and strippers, a mid-IR spectral range for organic functional group vibrational excitation and analysis is required. Near IR (NIR) would be inadequate for use in tracking organic molecules such as those specifically required and discussed by Shen et al. On the other hand, NIR is the preferred range for analyzing a complex chemical matrix.

In view of the fact that there are elements and/or limitations discussed above appearing in the present inventors' independent claim 14 which are absent in Shen et al, the inventors believe that the requirements for a rejection under 35 USC §102(b) have not been met and the rejection of claim 14 is traversed.

Based on the arguments given above, independent Claim 14, as amended, should be allowed as patentably distinct over Shen et al. Claims 15-16, 18, 21-24, 26, 28, 32 and 33 are all dependent claims and should be allowed if the independent claim (Claim 14) from which they depend is allowed. Nonetheless, the following comments with respect to the dependent claims are in order.

With respect to Claim 15, the infrared spectral range disclosed by Shen et al. differs from the near infrared range disclosed in the instant application. Claim 15 has been amended to explicitly include the infrared range used by the inventors, a range which does not overlap with the range used by Shen et al.

With respect to Claim 18, Shen et al. do not teach that the algorithm provides a rate of depletion of a chemical component. Shen measures the photoresist in the bath and its increase in concentration (Shen column 4, lines 40-41) and not a rate of depletion as required by the present inventors' claim 18. There is no explicit or even implicit discussion of rates in Shen et al.

With respect to Claim 24, while Shen et al. may teach converting a detected electronic signal to a concentration (Shen column 4, lines 22-25), this is not equivalent to a concentration rate of change as required in the present inventors' claim 24 ("supplying a concentration rate of change of at least one chemical component").

With respect to claim 32, Shen et al does not discuss an aqueous etchant solution containing inorganic etchant species, as recited in claim 32 of the present application. Shen's use of a "stripper acid" to describe monothalamine and dimethyl sulfoxide (Shen, column 4, lines 14-15) indicates that he is not contemplating ionic inorganic etchants. Nowhere in Shen et al. is there a direct teaching, or even an implied suggestion, that use of inorganic etchant species is contemplated.

#### ***Claim Rejections - 35 USC §103***

Claims 14-26, 28 and 30-33 stand rejected under 35 USC §103(a) as being unpatentable over the publication "In-Situ Chemical Concentration Control for Wafer Wet Cleaning" to Brause et al. in view of the publication "Quantification of Hydrofluoric Acid Species by Chemical Modeling Regression of Near-Infrared Spectra" to Thompson et al.

Claims 27 and 29 stand rejected under 35 USC §103(a) as being unpatentable over the publication "In-Situ Chemical Concentration Control for Wafer Wet Cleaning" to Brause et al. in

view of the publication "Quantification of Hydrofluoric Acid Species by Chemical Modeling Regression of Near-Infrared" to Thompson et al and further in view of JP 63307334 A to Nogami.

As indicated by the examiner, Brause et al. teach the use of conductivity measurements to control the concentrations of hydrofluoric acid (HF) etching solutions (and RA cleaning solutions) used in semiconductor wafer fabrication processes. As also indicated by the examiner, Thompson et al. teach that NIR spectroscopy may be used to detect HF and HF dimerization and disassociation products in aqueous solution. Thompson et al. uses NIR radiation of relatively short wavelength in conjunction with spectrophotometric titration and multivariate model-based regression analysis (see publication abstract) in an attempt to provide detection of each of the species known to be involved in HF equilibria in aqueous solution. He, as does Brause, restricts the species being investigated to HF, F<sup>-</sup>, HF<sub>2</sub><sup>-</sup>, H<sup>+</sup> and OH<sup>-</sup>.

Contrary to these teachings, the present inventors have recognized that semiconductor etch rates, as for example in the case of HF etchant solutions, depend on several species (principally, HF, F<sup>-</sup>, HF<sub>2</sub><sup>-</sup>, H<sup>+</sup> and OH<sup>-</sup>) that provide different etch rates and are present in equilibrium. Moreover, the etch rates are dependent on byproduct species which themselves have etching properties (see paragraphs [0250]-[0255] of the instant application). These byproducts build up species during the etching process. In the case of HF etching silicon containing wafers, the present inventors have realized that fluorosilicic acid and its substituted fluorosilicic acid species must be taken into account in the etching process and they must be included in the model from which the control algorithm is built.

The present inventors believe that nowhere in Brause, or Brause in view of Thompson (or Brause in view of Thompson and further in view of Nogami) are all the limitations of amended claim 14 taught or suggested. Specifically, nowhere in any of the cited three references, taken individually or in any combination, is there any teaching or suggestion of a byproduct having etchant properties, the byproducts being formed by the action of an inorganic etchant species on an inorganic solid, such byproducts being factored into the algorithm and model thereof.

Thompson's work is solely on aqueous HF solutions. The presence of a solid to be etched is absent and therefore byproducts formed from a solid and an etchant species, as claimed by the inventors' in claim 14, must therefore be absent. Similarly Brause does not discuss byproducts, except negatively. Brause, page 28, first paragraph under the title "Etching of SiO<sub>2</sub>" says *inter*

*alia* that for his system to work **there must be a linear relationship between HF concentration and conductivity. For this relationship to exist he states that there must be "...an absence of foreign matters in the etch solution (e.g. large amounts of etch byproducts)..."** (emphasis added). This explicitly indicates that he believes that process control would be difficult if byproducts, and, by inference, certainly byproducts having strong etchant properties such as fluorosilicic acids, were present.

The etchant byproducts included in claim 14 of the present invention increase the etch rate during the etching process. Their presence must be accounted for in the mathematical treatment of the spectral data, and the control algorithm *inter alia* should take these etchant byproducts into account. Their required presence in a process control algorithm is neither taught nor suggested in any of the Brause, Thompson or Nogami references.

To establish *prima facie* obviousness of a claimed invention (a rejection under 35 USC §103(a)), all the claim limitations must be taught or suggested by the prior art. Accordingly, in view of the fact that there are elements and/or limitations which have been discussed above and which appear in the present inventors' amended independent claim 14 that are neither taught nor suggested in Brause et al, Thompson et al and Nogami when taken singly or in any combination, the present inventors do not believe that the requirements for a rejection under 35 USC §103(a) have been met and the rejection is traversed.

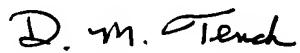
Since amended independent claim 14 should be allowable for the reasons discussed above, claims 14-26, 27-19 and 30-33, which depend directly or indirectly from amended independent claim 14, should also be allowable.

Additionally, as noted above, Brause (page 28, first paragraph) under the title "Etching of SiO<sub>2</sub>" says inter alia that for his system to work there must be "**...an absence of foreign matters in the etch solution (e.g. large amounts of etch byproducts)...**" (emphasis added). Therefore, there is an explicit teaching away from the present invention which incorporates byproducts with etchant properties directly into its algorithm and model thereof. There would be no motivation or suggestion — the opposite being true — to use Thompson's NIR approach in the method of Brause as alleged in the Office Action to arrive at the present invention. For this reason, as well as for the reason noted above, the 35 USC §103(a) rejection of claim 14 is traversed and the claim is deemed allowable. All dependent claims which depend from claim 14 must therefore also be allowable.

## CONCLUSION

In view of the foregoing remarks, the application is believed to be in condition for allowance. Favorable reconsideration and allowance of the application are respectfully requested.

Respectfully submitted,



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